US007907941B2

(12) **United States Patent**
Twitchell, Jr.

(10) **Patent No.: US 7,907,941 B2**
(45) **Date of Patent: Mar. 15, 2011**

(54) **DETERMINING PRESENCE OF RADIO FREQUENCY COMMUNICATION DEVICE**

(75) Inventor: **Robert W. Twitchell, Jr.**, Cumming, GA (US)

(73) Assignee: **Terahop Networks, Inc.**, Alpharetta, GA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 642 days.

(21) Appl. No.: **11/618,931**

(22) Filed: **Jan. 1, 2007**

(65) **Prior Publication Data**

US 2007/0155327 A1 Jul. 5, 2007

Related U.S. Application Data

(60) Provisional application No. 60/766,223, filed on Jan. 1, 2006.

(51) **Int. Cl.**
H04M 3/00 (2006.01)

(52) **U.S. Cl.** **455/418**; 455/41.2; 455/419; 370/310; 235/462.1; 340/10.1

(58) **Field of Classification Search** 455/418, 455/99, 556, 557, 66, 553, 72, 466, 419, 455/41.2, 404.2, 456.1–456.6, 551, 9, 67.11, 455/115.1, 151.2, 343.1–343.6, 73; 370/310, 370/310.2, 328, 338; 340/10.33, 7.36, 10.34, 340/10.42, 10.52; 235/462.01–462.19

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,613,990 A 9/1986 Halpern
4,680,583 A 7/1987 Grover
4,775,999 A * 10/1988 Williams 455/435.1
4,794,368 A 12/1988 Grossheim
5,040,238 A 8/1991 Comroe et al.

(Continued)

FOREIGN PATENT DOCUMENTS

EP 0467036 A2 1/1992

(Continued)

OTHER PUBLICATIONS

"Scalable Routing Strategies for Ad hoc Wireless Networks", Atsushi Iwata et al., IEEE Journal on Selected Areas in Communications, Special Issue on Adhoc Networks, Aug. 1999, pp. 1369-1379.

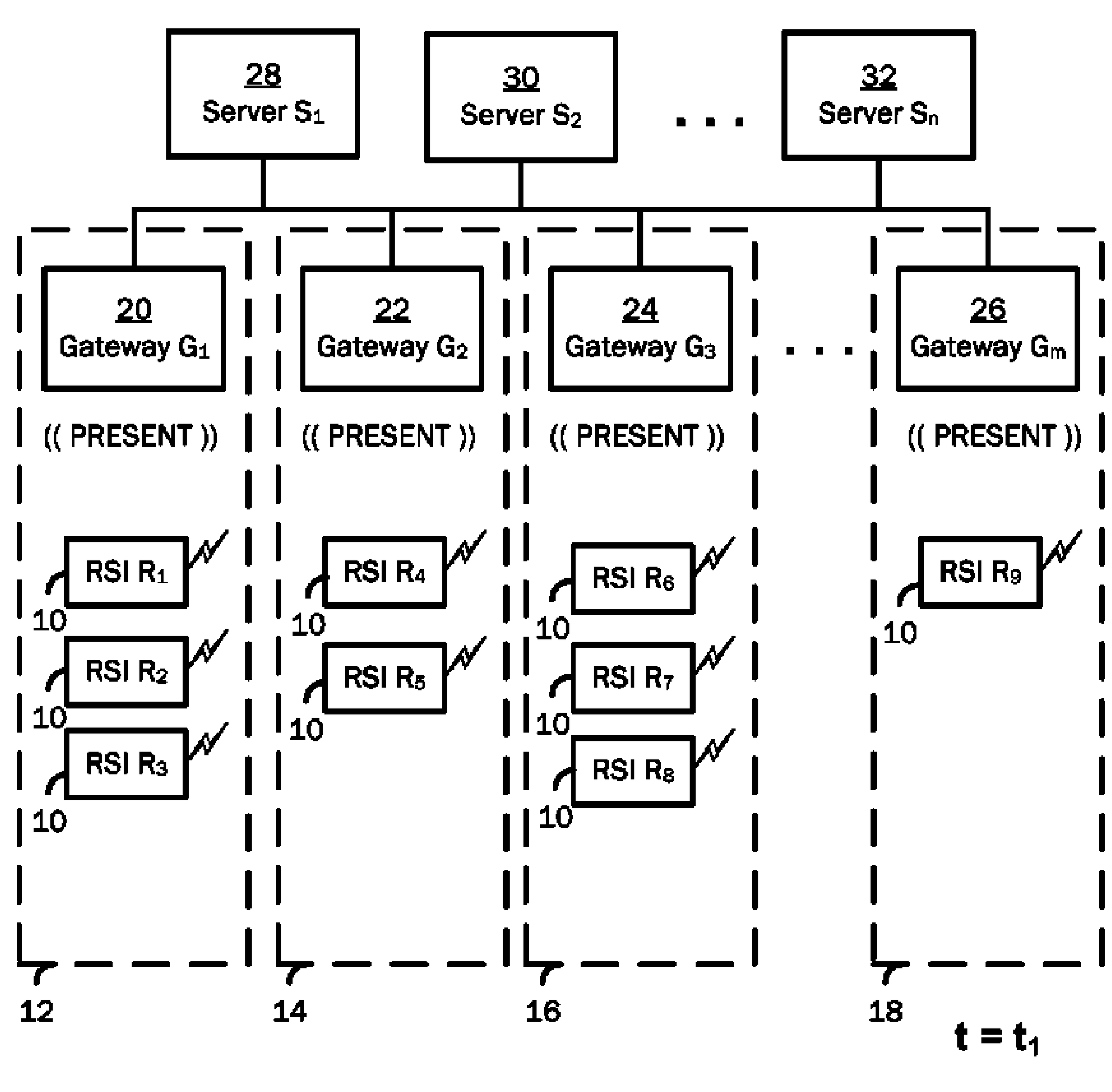
(Continued)

Primary Examiner — Kent Chang
Assistant Examiner — San Htun
(74) *Attorney, Agent, or Firm* — Tillman Wright, PLLC; Chad D. Tillman; Jeremy C. Doerre

(57) **ABSTRACT**

A radio frequency communication device includes a receiver; a transmitter; an interface for receiving one or more sensor signals based on sensor-acquired data that is indicative of a predetermined condition; and electronic components. The electronic components are arranged and configured such that the device operates in at least two states. In the first state, the device responds to a Present Broadcast by making a Present Response. In the second state, the device does not respond to a Present Broadcast with a Present Response. The electronic components further are arranged and configured such that the device enters the second state from the first state upon responding to a Present Broadcast with a Present Response, and such that the device enters the first state from the second state upon receiving, through the interface, one or more sensor signals based on sensor-acquired data that is indicative of a predetermined condition.

30 Claims, 8 Drawing Sheets



U.S. PATENT DOCUMENTS

5,117,501	A		5/1992	Childress et al.	
5,129,096	A		7/1992	Burns	
5,210,540	A		5/1993	Masumoto	
5,265,025	A		11/1993	Hirata	
5,295,154	A		3/1994	Meier et al.	
5,331,637	A		7/1994	Francis et al.	
5,369,784	A		11/1994	Nelson	
5,400,254	A		3/1995	Fujita	
5,425,051	A		6/1995	Mahany	
5,442,758	A		8/1995	Slingwine et al.	
5,511,232	A		4/1996	O'Dea et al.	
5,579,306	A		11/1996	Dent	
5,590,409	A		12/1996	Sawahashi et al.	
5,592,533	A	*	1/1997	McHenry et al.	455/435.2
5,596,652	A		1/1997	Piatek et al.	
5,604,892	A		2/1997	Nuttall et al.	
5,640,151	A		6/1997	Reis et al.	
5,649,286	A	*	7/1997	Frerking	455/435.1
5,652,751	A		7/1997	Sharony	
5,682,379	A		10/1997	Mahany et al.	
5,686,902	A		11/1997	Reis et al.	
5,732,077	A		3/1998	Whitehead	
5,761,195	A		6/1998	Lu et al.	
5,790,946	A		8/1998	Rotzoll	
5,793,882	A		8/1998	Piatek et al.	
5,833,910	A		11/1998	Teixido	
5,890,054	A		3/1999	Logsdon et al.	
5,907,491	A		5/1999	Canada et al.	
5,917,423	A		6/1999	Duvall	
5,939,982	A		8/1999	Gagnon et al.	
5,943,610	A		8/1999	Endo	
5,950,124	A		9/1999	Trompower et al.	
5,974,236	A		10/1999	Sherman	
5,977,913	A		11/1999	Christ	
6,005,884	A		12/1999	Cook et al.	
6,006,100	A		12/1999	Koenck et al.	
6,072,784	A		6/2000	Agrawal et al.	
6,078,789	A		6/2000	Bodenmann et al.	
6,091,724	A		7/2000	Chandra et al.	
6,097,707	A		8/2000	Hodzic et al.	
6,104,512	A		8/2000	Batey, Jr. et al.	
6,118,988	A		9/2000	Choi	
6,125,306	A		9/2000	Shimada et al.	
6,127,976	A		10/2000	Boyd et al.	
6,134,587	A		10/2000	Okanoue	
6,154,658	A	*	11/2000	Caci	455/466
6,192,400	B1		2/2001	Hanson et al.	
6,198,913	B1		3/2001	Sung et al.	
6,201,974	B1		3/2001	Lietsalmi et al.	
6,256,303	B1		7/2001	Drakoulis et al.	
6,313,745	B1		11/2001	Suzuki	
6,354,493	B1		3/2002	Mon	
6,360,169	B1		3/2002	Dudaney	
6,381,467	B1		4/2002	Hill et al.	
6,404,082	B1		6/2002	Rasinski et al.	
6,405,102	B1		6/2002	Swartz et al.	
6,409,082	B1		6/2002	Davis et al.	
6,418,299	B1		7/2002	Ramanathan	
6,424,260	B2		7/2002	Maloney	
6,424,264	B1		7/2002	Giraldin et al.	
6,427,913	B1		8/2002	Maloney	
6,473,607	B1		10/2002	Shohara et al.	
6,512,478	B1		1/2003	Chien	
6,529,142	B2		3/2003	Yeh et al.	
6,542,114	B1		4/2003	Eagleson et al.	
6,547,137	B1		4/2003	Begelfer et al.	
6,559,620	B2		5/2003	Zhou et al.	
6,600,418	B2		7/2003	Francis et al.	
6,611,556	B1		8/2003	Koener et al.	
6,614,349	B1		9/2003	Proctor et al.	
6,665,585	B2		12/2003	Kawase	
6,700,533	B1		3/2004	Werb et al.	
6,720,888	B2		4/2004	Eagleson et al.	
6,735,630	B1	*	5/2004	Gelvin et al.	709/224
6,737,974	B2		5/2004	Dickinson	
6,745,027	B2		6/2004	Twitchell, Jr.	
6,747,562	B2		6/2004	Giraldin et al.	
6,753,775	B2		6/2004	Auerbach et al.	
6,760,578	B2		7/2004	Rotzoll	
6,761,312	B2		7/2004	Piatek et al.	
6,765,484	B2		7/2004	Eagleson et al.	
6,816,063	B2		11/2004	Kubler et al.	
6,847,892	B2		1/2005	Zhou et al.	
6,934,540	B2		8/2005	Twitchell, Jr.	
6,940,392	B2		9/2005	Chan et al.	
6,972,682	B2	*	12/2005	Lareau et al.	340/568.1
6,975,614	B2		12/2005	Kennedy	
6,975,941	B1	*	12/2005	Lau et al.	701/213
7,012,529	B2		3/2006	Sajkowsky	
7,027,773	B1		4/2006	McMillin	
7,072,668	B2	*	7/2006	Chou	455/456.1
7,098,784	B2		8/2006	Easley et al.	
7,126,470	B2		10/2006	Clift et al.	
7,133,704	B2		11/2006	Twitchell, Jr.	
7,142,121	B2		11/2006	Chan et al.	
7,155,264	B2		12/2006	Twitchell, Jr.	
7,191,934	B2		3/2007	Miller et al.	
7,200,132	B2		4/2007	Twitchell, Jr.	
7,209,468	B2		4/2007	Twitchell, Jr.	
7,209,771	B2		4/2007	Twitchell, Jr.	
7,221,668	B2		5/2007	Twitchell, Jr.	
2001/0000019	A1		3/2001	Bowers et al.	
2002/0002627	A1	*	1/2002	Stead et al.	709/250
2002/0039896	A1		4/2002	Brown	
2002/0089421	A1	*	7/2002	Farringdon et al.	340/506
2002/0098861	A1		7/2002	Doney et al.	
2002/0119770	A1		8/2002	Twitchell, Jr.	
2002/0146985	A1		10/2002	Naden	
2003/0019929	A1	*	1/2003	Stewart et al.	235/385
2003/0083064	A1		5/2003	Cooper	
2003/0141973	A1		7/2003	Yeh et al.	
2003/0144020	A1		7/2003	Challa et al.	
2003/0179073	A1		9/2003	Ghazarian	
2003/0209601	A1		11/2003	Chung	
2004/0021572	A1		2/2004	Schoen et al.	
2004/0041731	A1		3/2004	Hisano	
2004/0082296	A1		4/2004	Twitchell, Jr.	
2004/0100415	A1		5/2004	Veitch et al.	
2004/0121793	A1		6/2004	Weigele et al.	
2004/0135691	A1		7/2004	Duron et al.	
2004/0183673	A1		9/2004	Nageli	
2005/0043068	A1		2/2005	Shohara et al.	
2005/0093702	A1		5/2005	Twitchell, Jr.	
2005/0093703	A1		5/2005	Twitchell, Jr.	
2005/0114326	A1	*	5/2005	Smith et al.	455/557
2005/0215280	A1		9/2005	Twitchell, Jr.	
2005/0226201	A1		10/2005	McMillin	
2006/0202817	A1		9/2006	Mackenzie et al.	
2006/0270382	A1		11/2006	Lappetelainen et al.	
2009/0103462	A1		4/2009	Twitchell, Jr.	

FOREIGN PATENT DOCUMENTS

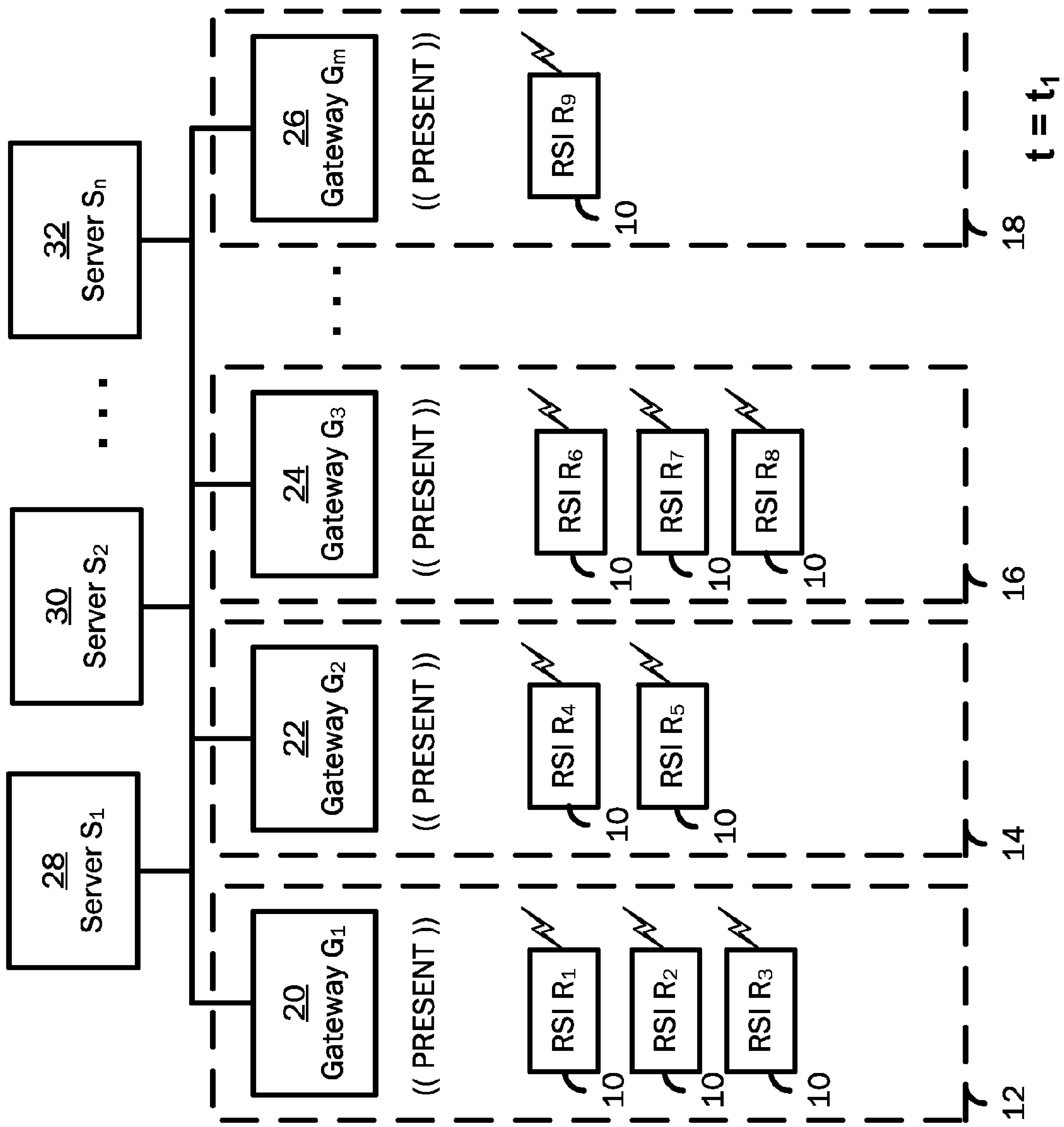
EP	0748083		12/1996
EP	0748085		12/1996
EP	0829995		3/1998
EP	1317733	A2	6/2003
EP	1692599	A2	8/2006
EP	1692668	A2	8/2006
WO	WO0068907		11/2000
WO	WO0069186		11/2000

OTHER PUBLICATIONS

"Cluster Based Routing Protocol", Internet-Draft Mingliang, Jiang et al., National University of Singapore, Jul. 1999.
Gary Morgan, Miniature Tags Provide Visibility & Cohesion for an LIA Battalion Level 'Proof of Principle', Pacific NW National Laboratory, Apr. 2001, Gary.morgan@pnl.gov.
Ben Sommer et al., Group 4, Passive RF Tags.
Kevin Sharp, Physical Reality: A Second Look, Supply Chain Systems, http://www.idsystems.com/reader/1999_03/phys0399_pt2/index.htm, Mar. 1999, Helmers Publishing, Inc.
U.S. Appl. No. 60/444,029, of Nageli, filed Jan. 31, 2003.
Ram Ramanathan et al., Hierarchically-Organized, Multihop Mobile Wireless Networks for Quality-of-Service Support, pp. 1-35, 1998.
Guangyu Pei et al., Mobility Management in Hierarchical Multi-hop Mobile Wireless Networks, 6 pages, 1999.

http://www/iprg/nokia.com/charliep/txt/manet/term.txt, Mobile Ad Hoc Networking Terminology, C. Perkins, Nov. 17, 1998, visited Nov. 13, 2000.
Daniel Lihui Gu et al., C-ICAMA, A Centralized Intelligent Channel Assigned Multiple Access for Multi-Layer Ad-Hoc Wireless Networks with UAVs, 6 pages, 2000.
Atsushi Iwata, et al., Scalable Routing Strategies for Ad Hoc Wireless Networks, IEEE Journal on Selected Areas in Communications, vol. 17, No. 8, Aug. 1999, pp. 1369-1379.
http://www.cs.ucla.edu/NRL/wireless/PAPER/draft-ietf-manet-admrp-02.txt, Sung-Ju Lee et al., On-Demand Multicast Routing Protocol (ODMRP) for Ad Hoc Networks, Jan. 2000, visited Nov. 13, 2000.
Guangyu Pei, et al., A Wireless Hierarchical Routing Protocol with Group Mobility, 1998 IEEE, 5 pages.
Charles E. Perkins, AD HOC Networks, Jan. 2001, table of contents, chapters 1, 4, and 11.
J.J. Gardia-Luna-Aceves et al., Source-Tree Routing in Wireless Networks, 1999, 10 pages.
Jean-Pierre Hubaux et al., Toward Self-Organized Mobile Ad Hoc Networks: The Terminodes Project, IEEE Communications Magazine, Jan. 2001, pp. 118-124.
Jaap Haartsen et al., Bluetooth: Vision, Goals, and Architecture, Mobile Computing & Communications Review, vol. 1, No. 2, 1998, 8 pages.
Jaap Haartsen, Bluetooth-The Universal Radio Interface for Ad Hoc, Wireless Connectivity, Ericsson Review No. 3, pp. 110-117, 1998.
Daniel Lihui Gu et al., Hierarchical Routing for Multi-Layer Ad-Hoc Wireless Networks with UAV's, 5 pages, 2000.
U.S. Appl. No. 60/499,338, of Easley et al., filed Sep. 3, 2003.
Keshavarzian et al., Energy-Efficient Link Assessment in Wireless Sensor Networks, INFOCOM 2004. 23rd Annual Joint Conference of the IEEE Computer and Communications Societies, vol. 3, 2004, pp. 1751-1761.
Stojmenovic et al., Design Giudelines for Routing Protocols in Ad Hoc and Sensor Networks with a Realistic Physical Layer, Communications Magazine, IEEE, vol. 43, Issue 3, Mar. 2005, pp. 101-106.
Melodia et al., On the Interdependence of Distributed Topology Control and Geographical Routing in Ad Hoc and Sensor Networks, Selected Areas in Communications, IEEE Journal, vol. 23, Issue 3, Mar. 2005, pp. 520-532.
Information Disclosure Statement (IDS) Letter Regarding Common Patent Application(s), dated Oct. 6, 2010.

* cited by examiner



28
Server S_1
30
Server S_2
32
Server S_n
20
Gateway G_1
22
Gateway G_2
24
Gateway G_3
26
Gateway G_m
((PRESENT))
((PRESENT))
((PRESENT))
((PRESENT))
RSI R_1
RSI R_2
RSI R_3
RSI R_4
RSI R_5
RSI R_6
RSI R_7
RSI R_8
RSI R_9
10
12
14
16
18
$t = t_1$

FIG. 1

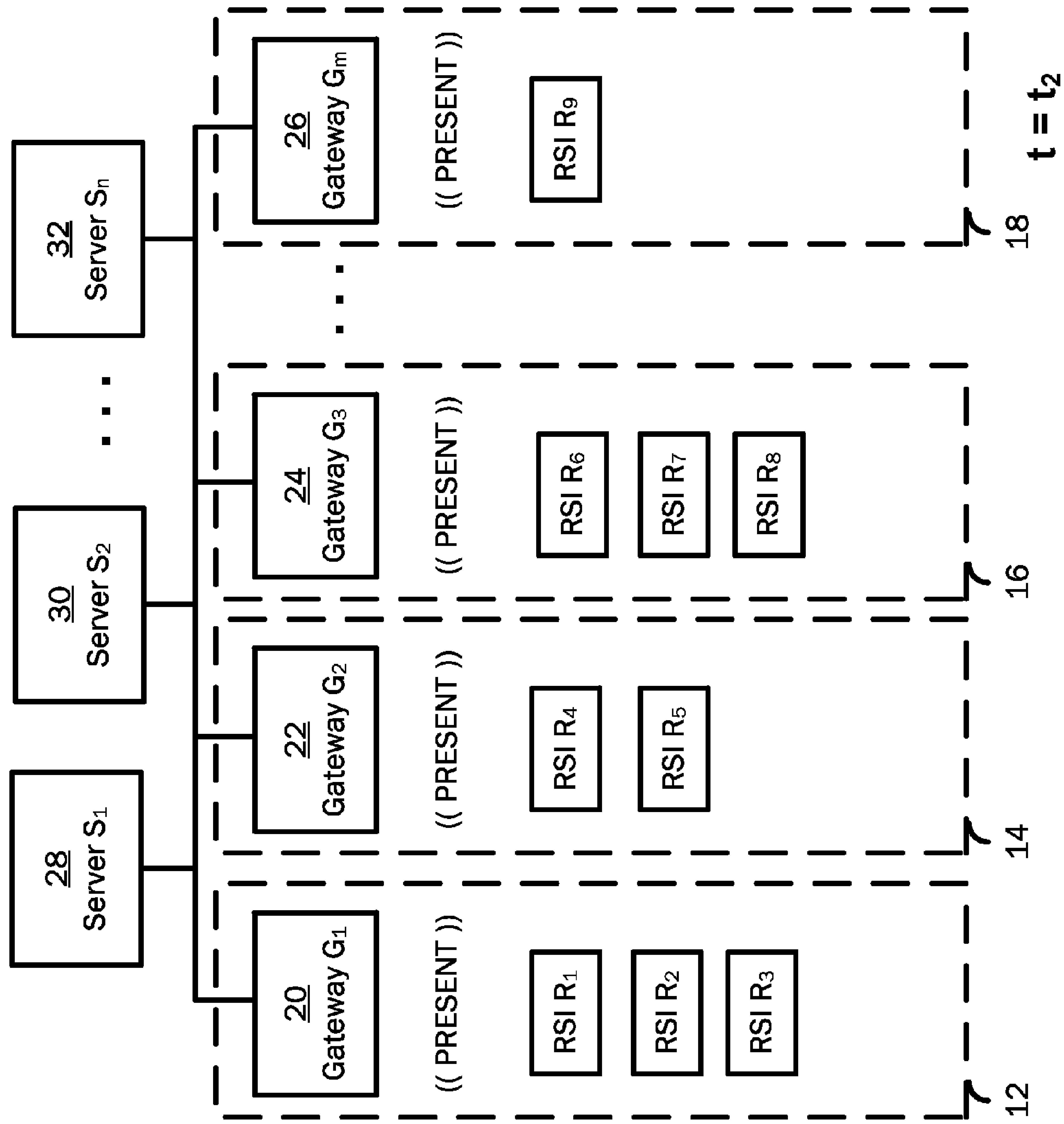

28
Server S_1
30
Server S_2
32
Server S_n
20
Gateway G_1
22
Gateway G_2
24
Gateway G_3
26
Gateway G_m
((PRESENT))
((PRESENT))
((PRESENT))
((PRESENT))
RSI R_1
RSI R_2
RSI R_3
RSI R_4
RSI R_5
RSI R_6
RSI R_7
RSI R_8
RSI R_9
12
14
16
18
$t = t_2$

FIG. 2

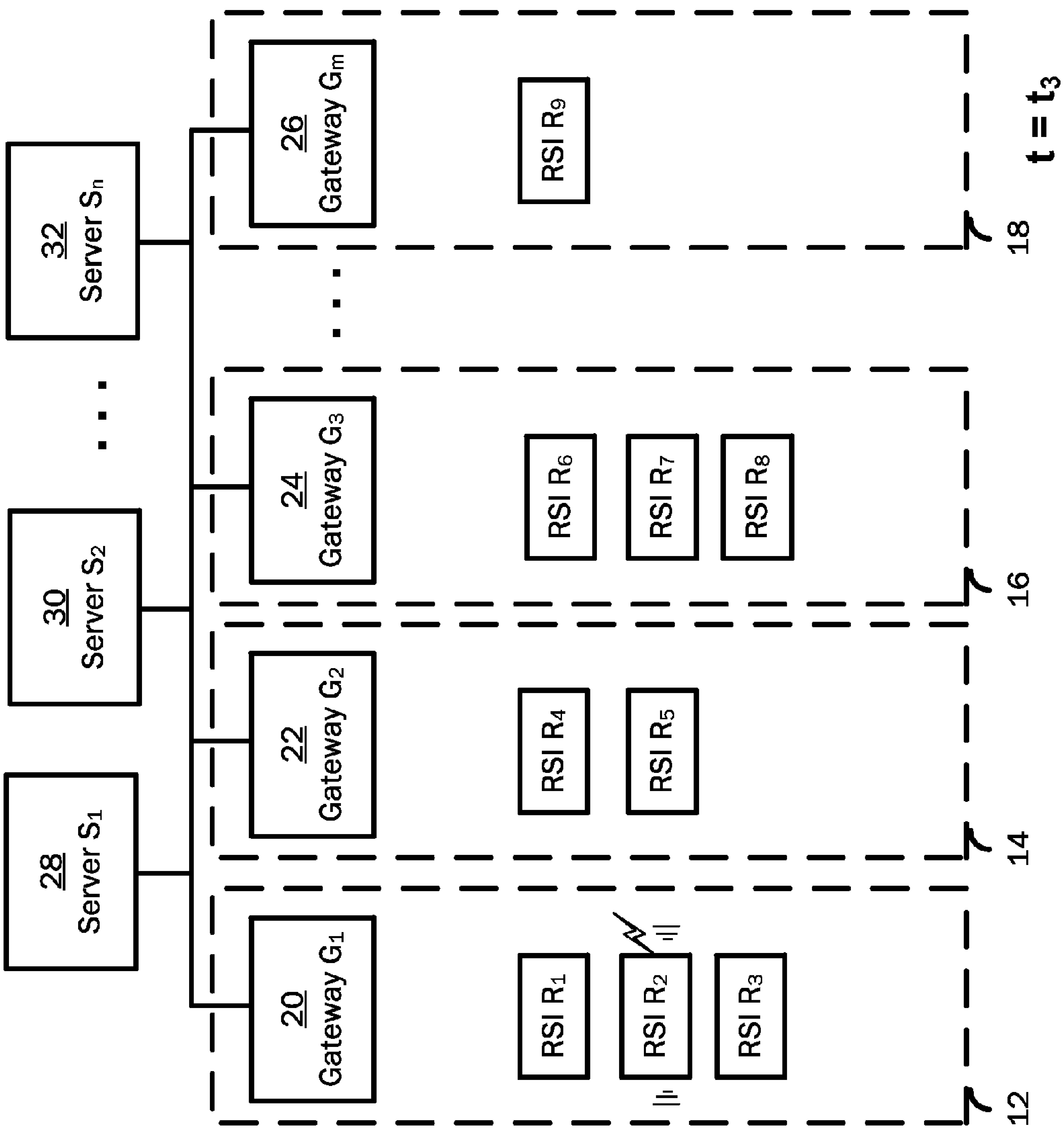

28 Server S_1
30 Server S_2
32 Server S_n
20 Gateway G_1
22 Gateway G_2
24 Gateway G_3
26 Gateway G_m
RSI R_1
RSI R_2
RSI R_3
RSI R_4
RSI R_5
RSI R_6
RSI R_7
RSI R_8
RSI R_9
12
14
16
18
$t = t_3$

FIG. 3

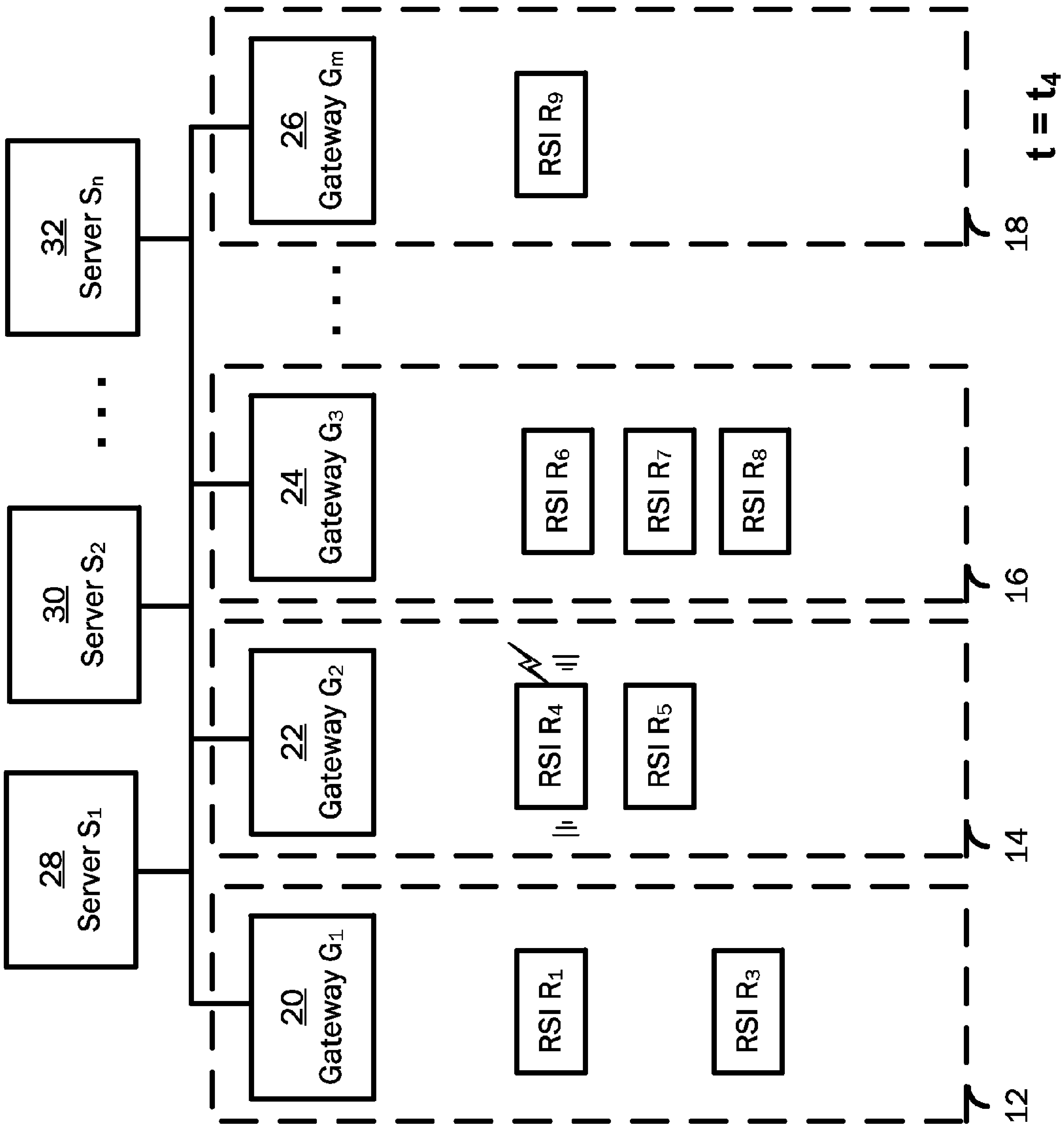

28
Server S_1
30
Server S_2
32
Server S_n
20
Gateway G_1
22
Gateway G_2
24
Gateway G_3
26
Gateway G_m
RSI R_1
RSI R_3
RSI R_4
RSI R_5
RSI R_6
RSI R_7
RSI R_8
RSI R_9
12
14
16
18
$t = t_4$

FIG. 4

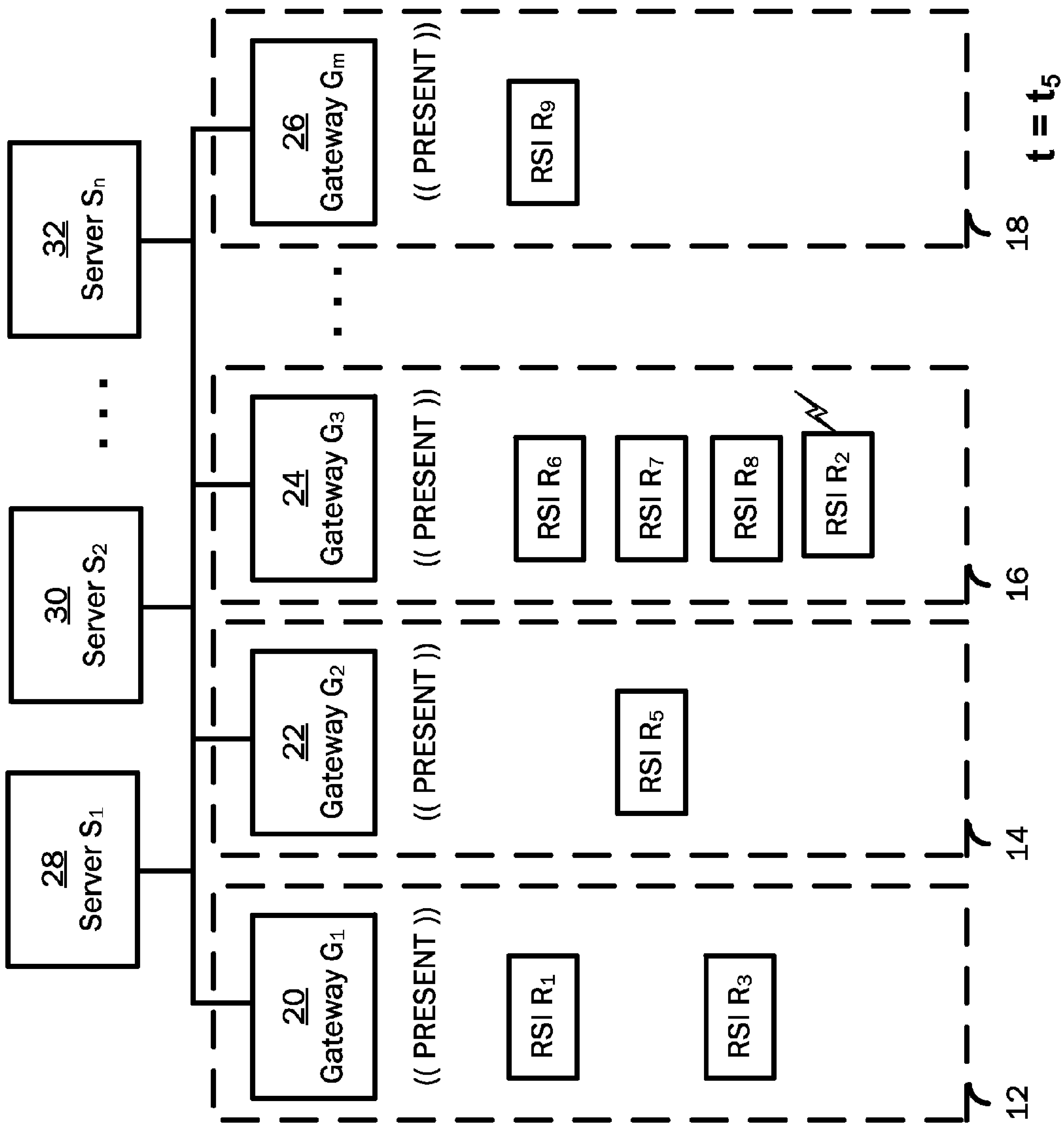
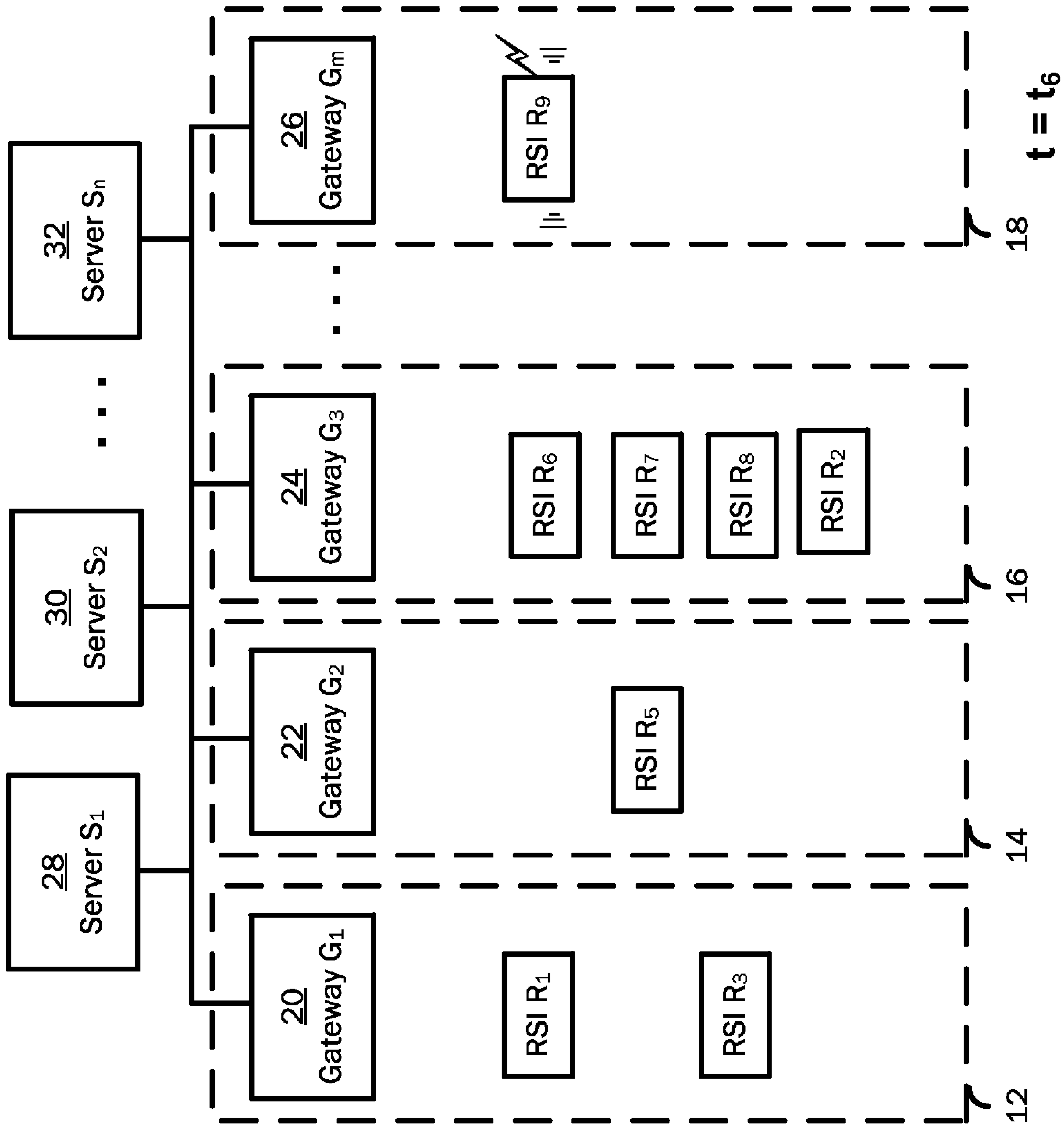

28
Server S_1
30
Server S_2
32
Server S_n
20
Gateway G_1
22
Gateway G_2
24
Gateway G_3
26
Gateway G_m
((PRESENT))
((PRESENT))
((PRESENT))
((PRESENT))
RSI R_1
RSI R_3
RSI R_5
RSI R_6
RSI R_7
RSI R_8
RSI R_2
RSI R_9
12
14
16
18
$t = t_5$

FIG. 5



28
Server S_1
30
Server S_2
32
Server S_n
20
Gateway G_1
22
Gateway G_2
24
Gateway G_3
26
Gateway G_m
RSI R_1
RSI R_3
RSI R_5
RSI R_6
RSI R_7
RSI R_8
RSI R_2
RSI R_9
12
14
16
18
$t = t_6$

FIG. 6

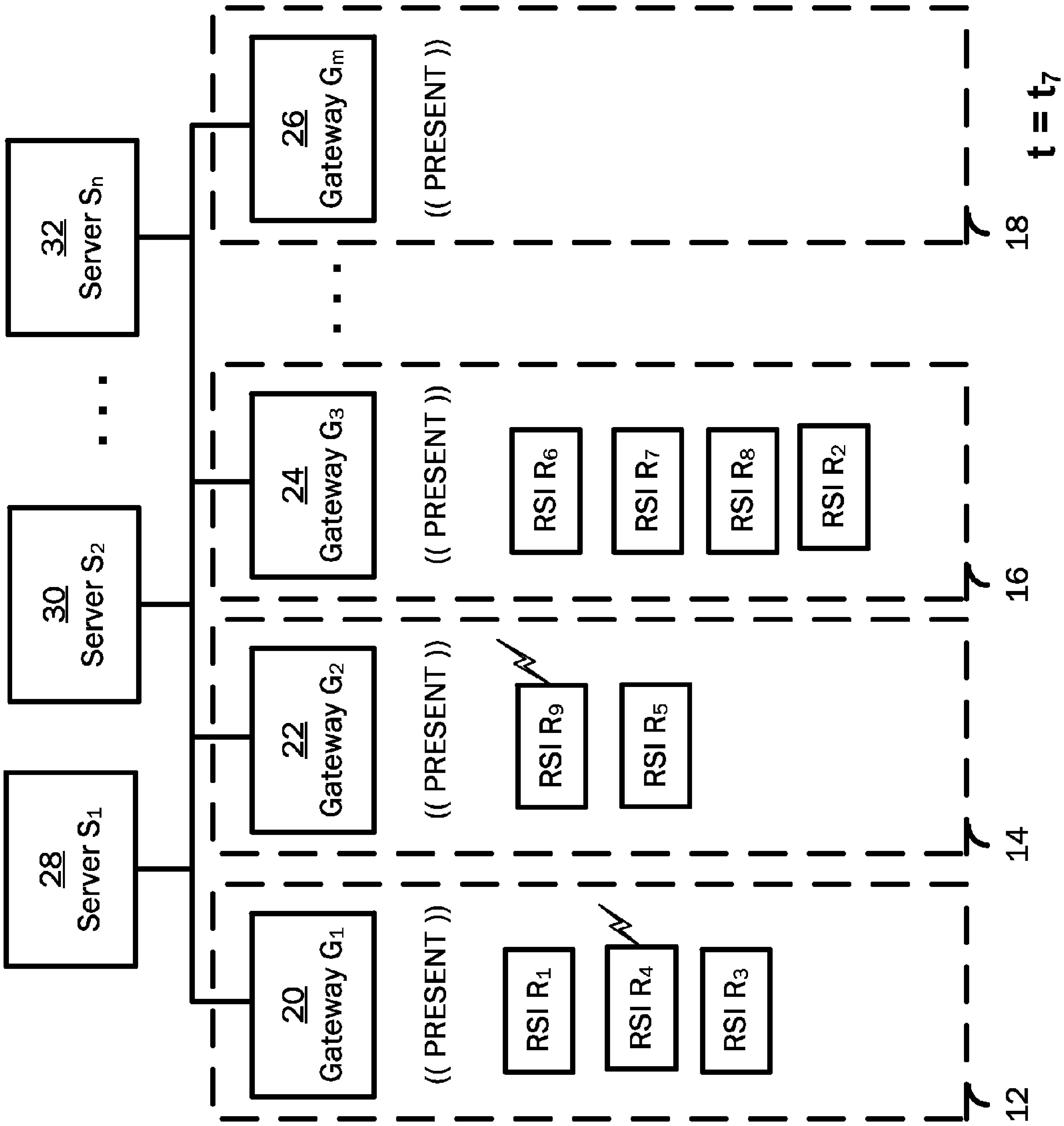

28
Server S_1
30
Server S_2
32
Server S_n
20
Gateway G_1
22
Gateway G_2
24
Gateway G_3
26
Gateway G_m
((PRESENT))
((PRESENT))
((PRESENT))
((PRESENT))
RSI R_1
RSI R_4
RSI R_3
RSI R_9
RSI R_5
RSI R_6
RSI R_7
RSI R_8
RSI R_2
12
14
16
18
$t = t_7$

FIG. 7

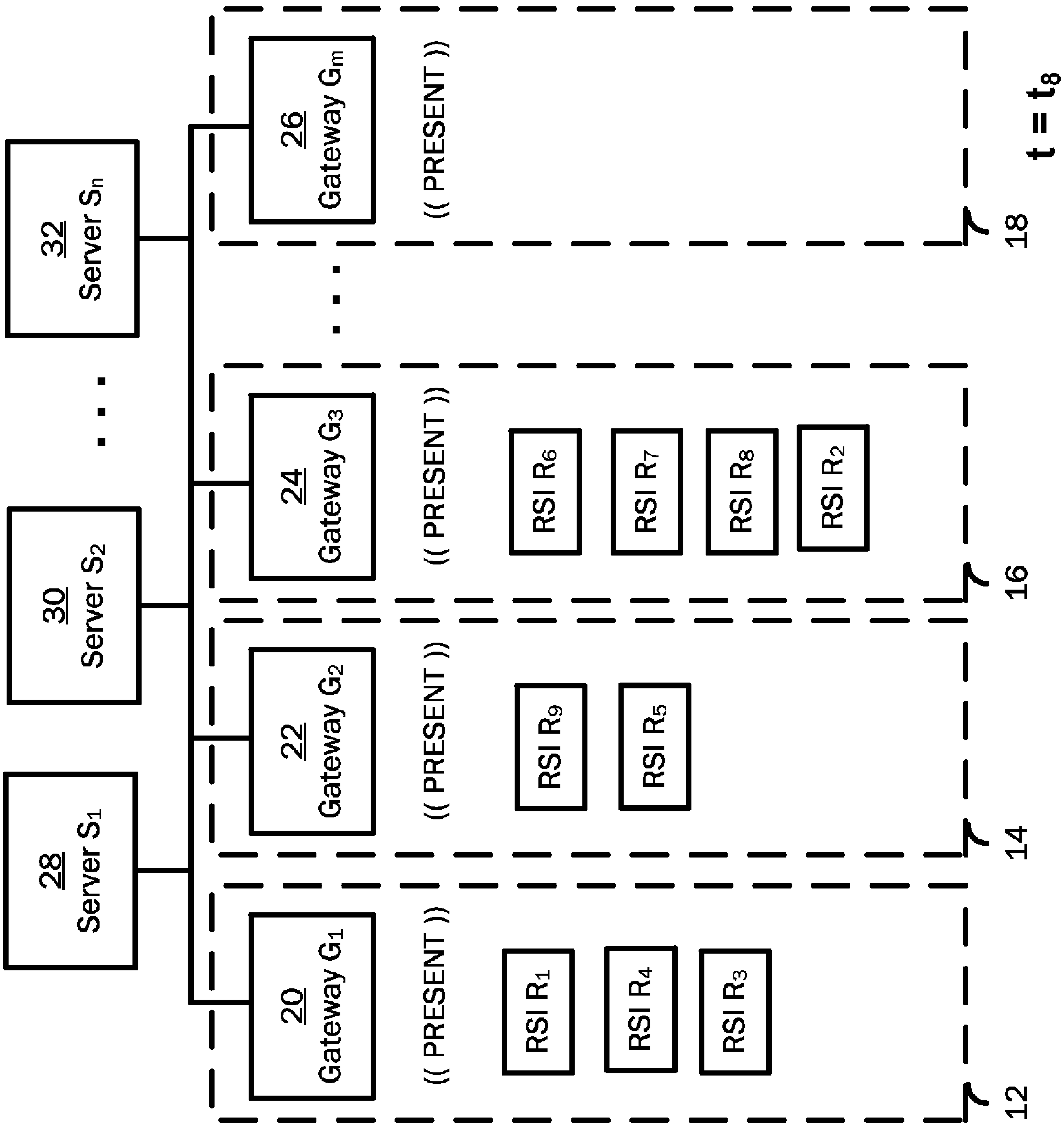

28
Server S_1
30
Server S_2
32
Server S_n
20
Gateway G_1
22
Gateway G_2
24
Gateway G_3
26
Gateway G_m
((PRESENT))
((PRESENT))
((PRESENT))
((PRESENT))
RSI R_1
RSI R_4
RSI R_3
RSI R_9
RSI R_5
RSI R_6
RSI R_7
RSI R_8
RSI R_2
12
14
16
18
$t = t_8$

FIG. 8

DETERMINING PRESENCE OF RADIO FREQUENCY COMMUNICATION DEVICE

I. CROSS-REFERENCE TO RELATED PATENT APPLICATIONS

The present patent application claim priority under the Paris Convention to U.S. patent application Ser. No. 60/766,223, filed Jan. 1, 2006, which patent application is hereby incorporated herein by reference. For purposes of the United States, the present patent application further is a U.S. non-provisional patent application of, and claims priority under 35 U.S.C. §119(e) to, U.S. patent application Ser. No. 60/766,223, filed Jan. 1, 2006, which patent application is hereby incorporated herein by reference. Furthermore, the present application hereby incorporates by reference each of the following patent application publications and patents, each of which is owned by the assignee of the present application: U.S. Pat. No. 7,155,264; U.S. Pat. No. 7,133,704; U.S. Pat. No. 6,934,540; U.S. Pat. No. 6,745,027; U.S. Patent Application Publication No. US 2006/0018274; U.S. Patent Application Publication No. US 2005/0215280; U.S. Patent Application Publication No. US 2006/0023679; U.S. Patent Application Publication No. US 2006/0023678; U.S. Patent Application Publication No. US 2006/0023678; U.S. Patent Application Publication No. US 2006/0023679; U.S. Patent Application Publication No. US 2006/0237490; U.S. Patent Application Publication No. US 2006/0276963; U.S. Patent Application Publication No. US 2006/0282217; U.S. Patent Application Publication No. US 2006/0276161; U.S. Patent Application Publication No. US 2006/0289204; U.S. Patent Application Publication No. US 2006/0274698; U.S. Patent Application Publication No. US 2006/0287822; and U.S. Patent Application Publication No. US 2006/0287008.

II. COPYRIGHT STATEMENT

III. BACKGROUND OF THE INVENTION

Conventional systems for tracking and/or monitoring assets (herein generally referred to as "asset tracking systems") utilize wireless tags that generally respond to any broadcast that is made. The wireless tags usually are passive, and the responses that the passive wireless tags make are often referred to as "chirps."

More sophisticated asset tracking systems utilize semi-passive wireless tags and/or active wireless tags. A semi-passive wireless tag includes an internal power source for transmitting, and an active wireless tag includes an internal power source for both receiving and transmitting. Semi-passive and active wireless tags generally have greater capabilities than passive wireless tags due to the internal power sources. Of course, power consumption is always a concern when a wireless tag includes an internal power source, since the internal power supply limits the useful life of the wireless tag, after which time maintenance is required (e.g., replacement of the internal power source).

In improved asset tracking systems, such as those disclosed in the above patent applications and patents that have been incorporated herein by reference, a wireless tag responds to a broadcast if the broadcast includes a common designation matching a common designation of the wireless tag. Such a common designation may comprise, for example, an "asset class" associated with the wireless tag. Ad hoc networks further may be created based on such classes, which ad hoc networks are referred to as "class based" networks.

Class based networks (and common designation networks in general) are beneficial because, in such networks, a communication device, such as a wireless tag, generally only transmits a response to a broadcast if the broadcast includes a class (or common designation) that matches a class (or common designation) of that communication device. Indeed, in a communication device employing a wakeup sequence of one or more of the patent references incorporated herein by reference, such communication device does not even process a broadcast once it is determined that the broadcast fails to include a matching class of the communication device. Consequently, the internal power supply of a semi-passive or active communication device is not drained by needless processing and/or responses to broadcasts.

In asset tracking systems, it often is important to know the physical location of an asset. This could include knowing where the asset is within a limited physical area, such as a warehouse; this also could include knowing where the asset is within several different warehouses in several different geographical locations, as well as where the asset is during transit between such locations.

In a conventional asset tracking system in which communication devices comprising semi-passive or active radios are placed on the assets, a conventional method for acquiring visibility of the assets includes broadcasting within an area at regular intervals to solicit responses from all of the radios within the area. The responses from the radios reveal the radios, and thus the assets, that are in the area.

This method is not advantageous because the regular, repetitive broadcasts result in an unnecessary power drain of the responding radios. Interference also can occur if a large number of radios respond at the same time, thereby making it difficult to accurately identify all of the radios within the area that respond to the broadcast.

In an alternative conventional method, a timer is included with each radio and the radio is configured to transmit at periodic intervals as a function of the timer. The radio thereby alerts the tracking system as to the whereabouts of the radio and, thus, the asset with which it is associated. By including timers with each radio, the radios may transmit at differing times in order to avoid unnecessary interference. A radio also can be set to sleep between intervals and to be awoken by the timer for making its regular transmissions. This increases the useful life of the radios because the radios do not consume power by actively listening for broadcasts while sleeping.

This alternative method permits determinations as to the delivery and continued presence of an asset at a particular area. Nevertheless, this alternative method does include drawbacks. For instance, by using timers, the radios are inaccessible by the asset tracking system during the sleep periods. Another drawback is that the radios automatically awake and transmit without regard for their location and without regard for whether the transmission is actually warranted or even desired. In this respect, during transportation on a plane, a radio may awaken and transmit, which may cause unwanted interference with the operation of the airplane. Preprogrammed transmission at regular intervals also may reveal the presence of the asset to unauthorized persons snooping for such radio transmissions.

Accordingly, better asset tracking systems and methods are desired that minimize unnecessary power consumption and that reduce unnecessary transmissions by communication devices associated with assets.

IV. SUMMARY OF THE INVENTION

The present invention includes many aspects and features. Moreover, while many aspects and features relate to, and are described in, the context of asset tracking systems, the present invention is not limited to use only in asset tracking systems, as will become apparent from the following summaries and detailed descriptions of aspects, features, and one or more embodiments of the present invention. For instance, one or more aspects of the present invention may be utilized to determine the presence or arrival of a communication device within an area independent of any asset and/or independent of any asset tracking system. The present invention also is not limited to use in common designation or class-based networks, although in preferred embodiments common designation or class-based networks are used. Indeed, the present application may beneficially be used in asset tracking as well as sensor monitoring, hazmat monitoring, first responder scenarios, military activities and situations, mobile phone applications, and automobile dealer key tracking systems.

Accordingly, an aspect of the present invention relates to a radio frequency communication device that includes a receiver configured to receive radio frequency transmissions; a transmitter configured to make radio frequency transmissions; an interface for receiving a signal from a sensor (hereinafter "sensor signal"); and electronic components. In accordance with this aspect of the invention, the electronic components are arranged and configured such that the radio frequency communication device operates in at least two states.

In the first state, the radio frequency communication device responds to a radio frequency transmission that is received by the receiver and that includes data representative of an inquiry as to the presence of radio frequency communication devices within an area. The "data representative of an inquiry as to the presence of radio frequency communication devices within an area" simply may be a predefined value in a particular format within the broadcast in accordance with a predefined protocol. A radio frequency transmission that includes such data is sometimes referred to herein as a "Present Broadcast." The response to the Present Broadcast is made by the radio frequency communication device by making a radio frequency transmission with the transmitter that includes an identification of the radio frequency communication device. A radio frequency transmission that includes an identification of the radio frequency communication device making the transmission, and that is made in response to a Present Broadcast, is sometimes referred to herein as a "Present Response."

In the second state, the radio frequency communication device does not respond to a Present Broadcast with a Present Response; specifically, no response to a Present Broadcast comprising a radio frequency transmission is made with the transmitter that includes an identification of the radio frequency communication device, and preferably, no response to a Present Broadcast comprising a radio frequency transmission is made at all, whether including an identification of the radio frequency communication device or otherwise.

In further accordance with this aspect of the invention, the electronic components are arranged and configured such that the radio frequency communication device enters the second state from the first state upon responding to a Present Broadcast with a Present Response. The electronic components further are arranged and configured such that the radio frequency communication device enters the first state from the second state upon receiving, through the interface, a sensor signal based on sensor-acquired data that is indicative of a predetermined condition. The sensor signal itself may include the sensor-acquired data or may be representative of the sensor-acquired data and may indicate, for example, a state of the sensor. In any event, such sensor signal is deemed to provide "sensor-acquired information" through the interface.

In a feature of this aspect, the first and second states relate only to whether the communication device responds to a Present Broadcast. Thus, the communication device otherwise remains responsive to other broadcasts in general and/or remains responsive to transmissions directed to the device. For example, in class-based networks, the communication device preferably remains responsive to any transmission including a class to which it is a member, whether the communication device is in the first state or the second state. Such transmission to the communication device may relate to a change in sensor states; maintenance of the communication device (e.g., checking the status of the internal power supply); or enabling or disabling of certain features or capabilities of the communication device (including the practicing of the present invention). In an alternative—and less preferred—feature, the first and second states relate not only to whether the communication device responds to a Present Broadcast, but whether the communication device responds to any broadcast at all. In this respect, when the communication device is in the second state, the communication device may not respond to any broadcasts at all.

In yet another feature of this aspect, the electronic components are further configured such that the radio frequency communication device makes a radio frequency transmission upon receiving, through the interface, sensor-acquired information that indicates a predetermined condition.

In another feature of this aspect, the radio frequency communication device further includes a computer processor that processes received radio frequency transmissions and received sensor-acquired information. The computer processor preferably effects state changes of the radio frequency communication device as a function of received radio frequency transmissions and received sensor-acquired information.

In still yet another feature, the communication device enters the first state from the second state after a predetermined period of time has transpired according to a timer of the communication device. This feature is beneficial, for example, if a sensor associated with an radio frequency communication device fails and if the radio frequency communication device would not otherwise enter the first state from the second state. In this regard, the time period before the radio frequency communication device enters, by default, the first state from the second state may be a significant period of time.

In still yet another feature, the communication device enters the first state from the second state after a predetermined number of failed attempts to communicate with a server have occurred. This feature is beneficial, for example, in identifying radio frequency communication devices in a certain area that are having technical difficulties in their communications.

In still another feature, the radio frequency communication device enters the first state from the second state upon receipt, via the receiver of radio frequency communication device, of an instruction to enter the first state. The instruction may be specific to a particular radio frequency communication device or generic to a plurality of radio frequency communication devices. Furthermore, a special common designation, such as a special class, may be utilized whereby a broadcast to such common designation would instruct radio frequency communication device having that common designation to enter the first state. This feature is beneficial, for example, if a sensor associated with an radio frequency communication device fails and if the radio frequency communication device would not otherwise enter the first state from the second state. This enables, for example, a sever to look for a radio frequency communication device within a particular area.

Another aspect of the invention relates to a method performed by a radio frequency communication device. The method includes: the first steps of responding to a Present Broadcast with a Present Response and then not responding to any further Present Broadcasts; and, repeating the first steps upon receiving, through an interface of the radio frequency communication device, sensor-acquired information that is indicative of a predetermined condition. Thus, after receiving such sensor-acquired information, the radio frequency communication device does, in fact, respond to the next Present Broadcast.

In a feature of this aspect of the invention, the method further includes the step of making a radio frequency transmission with the transmitter of the radio frequency communication device upon receiving, through an interface of the radio frequency communication device, the sensor-acquired information indicative of the predetermined condition.

In accordance with this and other aspects of the invention, the predetermined condition may comprise movement of the radio frequency communication device; a change, exceeding a threshold, with respect to the location of the radio frequency communication device as determined based on GPS data; an/or a temperature associated with the radio frequency communication device exceeding a predetermined threshold. With further respect to location, for example, the data from the GPS receiver may be compared against a range of x-y coordinates for "geo fencing" of the communication device (e.g., 89.2412<x, 89.4522 and 145.2332<y<145.8772), with a predetermined condition being triggered by the GPS data that indicates the communication device being outside of a predefined geographical area. An examples of this is described below with regard to FIGS. **1**-**8**.

In further accordance with the invention, the predetermine condition may comprise a change in state of a sensor associated with a radio frequency communication device and the sensor may or may not indicate movement from an area. Such a state change could indicate, for example, the breaking of a magnetic seal or other seal of a container wherein the sensor monitors the seal of the container. The container could be, for example, a hazardous waste container or an international shipping container. In such case, the Present Broadcast could be used to reveal those containers for which the seals have been broken.

In another feature of the invention, the radio frequency communication device may comprises a node in one or more common designation networks. In this respect, the data representative of a general inquiry as to the presence of radio frequency communication devices may be a predefined common designation. Indeed, the data representative of a general inquiry as to the presence of radio frequency communication devices may be a common designation of "present."

In a related feature, the radio frequency communication device is associated with an asset being tracked in an asset tracking system. The asset tracking system may be a class based asset tracking system, and the data representative of a general inquiry as to the presence of radio frequency communication devices may be a predefined class designation. Indeed, the data representative of a general inquiry as to the presence of radio frequency communication devices may be a class designation of "present."

In addition to the aforementioned aspects and features of the present invention, the present invention further includes the various possible combinations of such aspects and features.

It will be appreciated that, in accordance with one or more aspects, determinations can be made as to when an asset has arrived in an area and when an asset has left the area. Furthermore, this can be achieved without significantly reducing battery life, and this can be achieved without unnecessary radio frequency transmissions.

V. BRIEF DESCRIPTION OF THE DRAWINGS

One or more preferred embodiments of the present invention now will be described in detail with reference to the accompanying drawings, wherein:

FIG. **1** is a first illustration representative of locations, states, and state transitions of radio frequency communication devices, at a first time, in accordance with one or more preferred embodiments of the present invention.

FIG. **2** is a second illustration representative of locations, states, and state transitions of radio frequency communication devices, at a second time subsequent to the first time, in accordance with one or more preferred embodiments of the present invention.

FIG. **3** is a third illustration representative of locations, states, and state transitions of radio frequency communication devices, at a third time subsequent to the second time, in accordance with one or more preferred embodiments of the present invention.

FIG. **4** is a fourth illustration representative of locations, states, and state transitions of radio frequency communication devices, at a fourth time subsequent to the third time, in accordance with one or more preferred embodiments of the present invention.

FIG. **5** is a fifth illustration representative of locations, states, and state transitions of radio frequency communication devices, at a fifth time subsequent to the fourth time, in accordance with one or more preferred embodiments of the present invention.

FIG. **6** is a sixth illustration representative of locations, states, and state transitions of radio frequency communication devices, at a sixth time subsequent to the fifth time, in accordance with one or more preferred embodiments of the present invention.

FIG. **7** is a seventh illustration representative of locations, states, and state transitions of radio frequency communication devices, at a seventh time subsequent to the sixth time, in accordance with one or more preferred embodiments of the present invention.

FIG. **8** is an eighth illustration representative of locations, states, and state transitions of radio frequency communication devices, at an eighth time subsequent to the seventh time, in accordance with one or more preferred embodiments of the present invention.

VI. DETAILED DESCRIPTION

As a preliminary matter, it will readily be understood by one having ordinary skill in the relevant art ("Ordinary Artisan") that the present invention has broad utility and application. Furthermore, any embodiment discussed and identified as being "preferred" is considered to be part of a best mode contemplated for carrying out the present invention. Other embodiments also may be discussed for additional illustrative purposes in providing a full and enabling disclosure of the present invention. Moreover, many embodiments, such as adaptations, variations, modifications, and equivalent arrangements, will be implicitly disclosed by the embodiments described herein and fall within the scope of the present invention.

Accordingly, while the present invention is described herein in detail in relation to one or more embodiments, it is to be understood that this disclosure is illustrative and exemplary of the present invention, and is made merely for the purposes of providing a full and enabling disclosure of the present invention. The detailed disclosure herein of one or more embodiments is not intended, nor is to be construed, to limit the scope of patent protection afforded the present invention, which scope is to be defined by the claims and the equivalents thereof. It is not intended that the scope of patent protection afforded the present invention be defined by reading into any claim a limitation found herein that does not explicitly appear in the claim itself.

Thus, for example, any sequence(s) and/or temporal order of steps of various processes or methods that are described herein are illustrative and not restrictive. Accordingly, it should be understood that, although steps of various processes or methods may be shown and described as being in a sequence or temporal order, the steps of any such processes or methods are not limited to being carried out in any particular sequence or order, absent an indication otherwise. Indeed, the steps in such processes or methods generally may be carried out in various different sequences and orders while still falling within the scope of the present invention. Accordingly, it is intended that the scope of patent protection afforded the present invention is to be defined by the appended claims rather than the description set forth herein.

Additionally, it is important to note that each term used herein refers to that which the Ordinary Artisan would understand such term to mean based on the contextual use of such term herein. To the extent that the meaning of a term used herein—as understood by the Ordinary Artisan based on the contextual use of such term—differs in any way from any particular dictionary definition of such term, it is intended that the meaning of the term as understood by the Ordinary Artisan should prevail.

Furthermore, it is important to note that, as used herein, "a" and "an" each generally denotes "at least one," but does not exclude a plurality unless the contextual use dictates otherwise. Thus, reference to "a picnic basket having an apple" describes "a picnic basket having at least one apple" as well as "a picnic basket having apples." In contrast, reference to "a picnic basket having a single apple" describes "a picnic basket having only one apple."

When used herein to join a list of items, "or" denotes "at least one of the items," but does not exclude a plurality of items of the list. Thus, reference to "a picnic basket having cheese or crackers" describes "a picnic basket having cheese without crackers", "a picnic basket having crackers without cheese", and "a picnic basket having both cheese and crackers." Finally, when used herein to join a list of items, "and" denotes "all of the items of the list." Thus, reference to "a picnic basket having cheese and crackers" describes "a picnic basket having cheese, wherein the picnic basket further has crackers," as well as describes "a picnic basket having crackers, wherein the picnic basket further has cheese."

Turning now to the drawings, FIG. **1** is representative of locations, states, and state transitions of radio frequency communication devices shown at a first time in accordance with one or more preferred embodiments of the present invention.

In this regard, nine radio frequency communication devices **10** labeled "RSI R_1" through "RSI R_9" are shown in FIG. **1**. Each radio frequency communication device **10** preferably comprises a movable remote sensor interface or "RSI" that includes its own internal power source, such as a battery. Each RSI preferably is active or at least semi-active, and each RSI preferably is disposed in electronic communication with one or more sensors through one or more interfaces of the RSI for receiving sensor signals including, for example, sensor-acquired data. Such sensors may comprise, for example, temperature sensors, motion sensors, accelerometer sensors, and GPS receivers.

The nine communication devices **10** are distributed among m different physical areas (m being some integer greater than 1). These areas are represented by areas **12**,**14**,**16**,**18** illustrated in FIG. **1**. Each area may be at the same location as another area or at a different location as another area. For instance, area **12** may represent a boat dock (area) at a port of entry (location) and area **14** may represent a truck loading dock (area) at the same port of entry (location). Alternatively, area **12** may represent a warehouse (area) in Charleston, S.C. (location) and area **14** may represent a warehouse (area) in San Diego, Calif. (location). Moreover, area **16** may represent the cargo area (area) of a transport vehicle (location) in route between area **12** in Charleston and area **14** in San Diego, and the location thus need not be stationary. In this example, the location is dynamic and changes as the transport vehicle moves between Charleston and San Diego.

Furthermore, in accordance with one or more aspects of the present invention, at least one of the sensors associated with an RSI is utilized to indicate the likely removal of the RSI from an area, as discussed in greater detail below.

Each of the m areas includes at least one gateway and, accordingly, there are at least m gateways represented in FIG. **1**. These gateways are represented by gateways **20**,**22**,**24**,**26**. In this regard, gateway **20** is illustrated as being within area **12** and is labeled "Gateway G_1"; gateway **22** is illustrated as being within area **14** and is labeled "Gateway G_2"; gateway **24** is illustrated as being within area **16** and is labeled "Gateway G_3"; and gateway **26** is illustrated as being within area **18** and is labeled "Gateway G_m".

Each gateway **20**,**22**,**24**,**26** preferably is disposed in electronic communication with one or more servers labeled, respectively, "Server S_1", "Server S_2", and "Server S_n", wherein n is some integer greater than 1. The servers are represented by server **28**,**30**,**32** and may be remotely located to each other. The servers **28**,**30**,**32** also may be remotely located to the gateways **20**,**22**,**24**,**26**. The electronic communication between the servers and the gateways may be accomplished, for example, by way of cellular communications, satellite communications, and/or Internet communications.

Preferably, the communication devices **10** are associated with assets, and the servers **28**,**30**,**32** collectively include the programs and databases of one or more asset tracking systems for tracking and/or monitoring of the assets with which the communication devices **10** are associated. The gateways and the communication devices further preferably form common designation networks and, more preferably, class based networks.

With further reference to FIG. **1**, each gateway **20**,**22**,**24**,**26** is shown at a first time t_1 in FIG. **1** as making a respective radio frequency transmission that preferably awakens each communication device **10** from a sleep or standby mode, as appropriate. In this regard, this radio frequency transmission preferably comprises a wakeup broadcast that includes a common designation comprising a class designation. If the class designation matches a class designation maintained in a table of class designations of a respective communication device **10**, then that communication device **10** awakens and makes a radio frequency transmission in response. For brevity, a radio frequency transmission that is a wakeup broadcast and that includes a class designation is sometimes referred to herein as a "Class-Present Wakeup Broadcast" and is simply labeled "Present" in the drawings. As will be appreciated, the Class-Present Wakeup Broadcasts represent a particular type of—and if a subset of—Present Broadcasts.

Additionally, the transmission in response to the Class-Present Wakeup Broadcast by the respective communication device **10** preferably includes an identification of the respective communication device **10**. Such an identification may uniquely identify the respective communication device **10** or radio of the communication device **10**. Alternatively, the identification may uniquely identify one or more assets with which the communication device **10** is associated in an asset tracking system, especially when the communication device is a wireless reader tag (WRT) or similar device. Alternatively, the identification may serve to distinguish the respective communication device **10** from one or more other communication devices **10** without uniquely identifying the respective communication device **10** from all other communication devices **10**.

The Class-Present Wakeup Broadcast made by each gateway **20**,**22**,**24**,**26** is received by each communication device within the respective area of the gateway, and each communication device **10** is shown as responding to the Class-Present Wakeup Broadcast, wherein each response is represented by a lightning bolt.

As will be appreciated, an RSI further can retransmit the Class-Present Wakeup Broadcast to other RSIs that fall outside of the gateway range, thereby expanding the effective range of communications with the gateway. Communications between a gateway and one or more RSIs outside of the gateway's range, via one or more RSIs within range, is disclosed in one or more of the incorporated references but, for clarity, is not shown in the present drawings. Communications between an RSI and a gateway further may be through other RSIs even when all RSIs are within range of the gateway, as disclosed, for example, in many of the incorporated references such as U.S. Pat. Nos. 6,745,027 and 6,934,540.

As will be appreciated from the following detailed description, and in accordance with preferred embodiments of the invention, the fact that each of the nine communication devices **10** responds to the Class-Present Wakeup Broadcast indicates that none of the nine communication devices **10** likely were present in the areas **12**,**14**,**16**,**18** as shown in FIG. **1** at the time of a Class-Present Wakeup Broadcast first preceding that at time t_1. Furthermore, each communication device **10** responds to a Class-Present Wakeup Broadcast, as appropriate, regardless of the number of times that the communication device **10** has previously responded. Whether a communication device **10** responds preferably is not a function of the number of times that communication device **10** has responded in the past.

The Class-Present Wakeup Broadcast may be performed by each respective gateway "on demand" upon receipt of an instruction to such effect from one of the servers **28**,**30**,**32**. Alternatively, each gateway may be configured to make the Class-Present Wakeup Broadcast in accordance with a predetermined schedule, such as at regular intervals of time. If timers are utilized, then the timers of the gateways determine the resolution within which a communication device is identified as having arrived at a particular area. Still yet, a particular gateway may be triggered to make a Class-Present Wakeup Broadcast by one or more sensors, such as motion, optical, or infrared sensors. Indeed, while gateways are concurrently shown in the drawings as making Class-Present Wakeup Broadcasts, a gateway nevertheless may make a Class-Present Wakeup Broadcast independent of one or more other gateways.

The transmissions made in response to the Class-Present Wakeup Broadcast and, in particular, the identification included in each response, is communicated through each gateway to an appropriate one or more of the servers **28**,**30**,**32** that is tasked with keeping track of the location of each communication device **10**. Based upon the particular gateway from which a respective identification is received, the server may then determine that the respective communication device **10** corresponding to that identification is within the area of that particular gateway.

Accordingly, from the responses to the Class-Present Wakeup Broadcasts shown in FIG. **1**, the appropriate server determines that: RSIs R_1, R_2, and R_3 are within the area of Gateway G_1; RSIs R_4 and R_5 are within the area of Gateway G_2; RSIs R_6, R_7, and R_8 are within the area of Gateway G_3; and RSI R_9 is within the area of Gateway G_m. Preferably, the server records and maintains such location information for each of the communication devices **10**.

Thereafter, each gateway **20**,**22**,**24**,**26** is shown at a second time subsequent to the first time in FIG. **2** as making a respective subsequent Class-Present Wakeup Broadcast. Again, the Class-Present Wakeup Broadcast made by each gateway **20**,**22**,**24**,**26** is received by each communication device within the respective area of the gateway; however, none of the communication devices **10** is shown as responding to the Class-Present Wakeup Broadcast. In accordance with preferred embodiments of the invention, none of the communication devices **10** respond to the Class-Present Wakeup Broadcast because each has already responded to a Class-Present Wakeup Broadcast at time t_1, and each has yet to move from the respective area in which it was located since that time.

As will be appreciated, the server tasked with keeping track of the location of each communication device **10** receives no identification from any communication device **10** via the gateways **20**,**22**,**24**,**26** and, based thereon, does not update any location information for any of the communication devices **10**. Having received no identifications in response to the Class-Present Wakeup Broadcasts, the server assumes that none of the communication devices **10** have been moved from their respective areas as recorded by the server.

At a third time subsequent to the second time, as shown in FIG. **3**, communication device **10** labeled as RSI R_2 is moved from the area **12** of the gateway **20** (Gateway G_1). The RSI R_2 preferably is disposed in electrical communication with a motion sensor through an interface thereof and, upon being moved, the RSI R_2 preferably receives sensor-acquired information from the motion sensor that indicates the movement of the RSI R_2. Such electrical communication may be wired or wireless, and the sensor may be internal or external to a housing of the communication device. The RSI R_2 preferably is configured, upon receipt of such sensor-acquired information through the interface, to make a radio frequency transmission including an identification thereof to an appropriate server via the gateway **20**. The server preferably is the server that records and maintains the location information for each of the communication devices **10** and, upon receipt of the communication from RSI R_2, the server preferably records information pertaining to such communication. In particular, the server preferably records information indicating movement of RSI R_2 and the time t_3 of such movement. The movement is presumed to indicate the likely removal of the RSI R_2

from the area. Other sensors, or a combination of sensors, further can be used to indicate such likely removal. For example, the combined readings from both a motion sensor and a temperature sensor could be used to indicate likely removal of the communication device from a particular area. Alternatively, temperature rather than motion could be used as an indicator that the communication device likely has moved from a controlled environment of a particular area.

At a fourth time subsequent to the third time, as shown in FIG. **4**, communication device **10** labeled as RSI R_4 is moved from the area **14** of the gateway **22** (Gateway G_2). The RSI R_4 preferably is disposed in electrical communication with a motion sensor through an interface thereof and, upon being moved, the RSI R_4 preferably receives sensor-acquired information from the motion sensor that indicates the movement of the RSI R_4. Such electrical communication may be wired or wireless, and the sensor may be internal or external to the RSI. The RSI R_4 preferably is configured, upon receipt of such sensor-acquired information through the interface, to make a radio frequency transmission including an identification thereof to an appropriate server via the gateway **22**. The server preferably is the server that records and maintains the location information for each of the communication devices **10** and, upon receipt of the communication from RSI R_4, the server preferably records information pertaining to such communication. In particular, the server preferably records information indicating movement of RSI R_2 and the time t_4 of such movement.

At a fifth time subsequent to the fourth time, as shown in FIG. **5**, the gateways **20**,**22**,**24**,**26** again make Class-Present Wakeup Broadcasts. As will be appreciated, none of the communication devices **10** respond to the Class-Present Wakeup Broadcast that have not moved since the first time t_1; such communications generally would be unnecessary and would thus needlessly drain power sources of the communication devices **10**. On the other hand, RSI R_2 which was moved at time t_3 has since moved into the area of gateway **24** (Gateway G_3) by time t_5 and, in response to the Class-Present Wakeup Broadcast received from gateway **24**, the RSI R_2 does make a responsive transmission that includes an identification thereof As a result of this responsive transmission, the server tracking the location information of RSI R_2 updates the location information to indicate that RSI R_2 now is in area **16** as of time t_5. RSI R_4, on the other hand, did not respond to the Class-Present Wakeup Broadcasts and, as such, its absence from areas **12**,**14**,**16**,**18** is identified. It further deemed that it was moved from area **14** at time t_4.

At a sixth time subsequent to the fifth time, as shown in FIG. **6**, communication device **10** labeled as RSI R_9 is moved from the area **18** of the gateway **26** (Gateway G_m). The RSI R_9 preferably is disposed in electrical communication with a motion sensor through an interface thereof and, upon being moved, the RSI R_9 preferably receives sensor-acquired information from the motion sensor that indicates the movement of the RSI R_9. Such electrical communication may be wired or wireless, and the sensor may be internal or external to the RSI. The RSI R_9 preferably is configured, upon receipt of such sensor-acquired information through the interface, to make a radio frequency transmission including an identification thereof to an appropriate server via the gateway **26**. The server preferably is the server that records and maintains the location information for each of the communication devices **10** and, upon receipt of the communication from RSI R_9, the server preferably records information pertaining to such communication. In particular, the server preferably records information indicating movement of RSI R_9 and the time t_6 of such movement.

At a seventh time subsequent to the sixth time, as shown in FIG. **7**, the gateways **20**,**22**,**24**,**26** again make Class-Present Wakeup Broadcasts. As will be appreciated, none of the communication devices **10** respond to the Class-Present Wakeup Broadcast that have not moved since the preceding Class-Present Wakeup Broadcast at time t_5; such communications generally would be unnecessary and would thus needlessly drain power sources of the communication devices **10**. On the other hand, RSI R_9 which was moved at time t_6 has since moved into the area **14** of gateway **22** (Gateway G_2) by time t_7 and, in response to the Class-Present Wakeup Broadcast received from gateway **22**, the RSI R_9 does make a responsive transmission that includes an identification thereof. As a result of this responsive transmission, the server tracking the location information of RSI R_9 updates the location information to indicate that RSI R_9 now is in area **14** as of time t_7.

Additionally, RSI R_4 which was moved at time t_4 has moved into the area **1** of gateway **20** (Gateway G_1) by time t_7 and, in response to the Class-Present Wakeup Broadcast received from gateway **20**, the RSI R_4 does make a responsive transmission that includes an identification thereof. As a result of this responsive transmission, the server tracking the location information of RSI R_4 updates the location information to indicate that RSI R_4 now is in area **10** as of time t_7.

Thereafter, each gateway **20**,**22**,**24**,**26** is shown in FIG. **8** making a respective subsequent Class-Present Wakeup Broadcast at an eighth time subsequent to the seventh. Again, the Class-Present Wakeup Broadcast made by each gateway **20**,**22**,**24**,**26** is received by each communication device within the respective area of the gateway; however, none of the communication devices **10** is shown as responding to the Class-Present Wakeup Broadcast. In accordance with preferred embodiments of the invention, none of the communication devices **10** responds to the Class-Present Wakeup Broadcast because each communication device **10** has already responded as late as time t_7 to a previous Class-Present Wakeup Broadcast and has yet to be moved since such time of response. Accordingly, no responsive transmissions are needlessly made by any of the communication devices **10**.

Each of the communication devices **10** shown in FIGS. **1-8** preferably operates in at least two states. In a first state, a communication device **10** responds to receipt of a Class-Present Wakeup Broadcast from a gateway **20**,**22**,**24**,**26** by making a transmission that includes an identification thereof. After this responsive transmission, the communication device **10** preferably enters a second state in which it does not respond to Class-Present Wakeup Broadcasts. The communication device **10** preferably remains in this second state until sensor-acquired information received through an interface thereof indicates that a predefined condition has occurred, such as movement of the communication device **10**. Upon the occurrence of the predefined condition, the communication device **10** preferably makes a transmission that includes an indication of the occurrence of the predefined condition as well as an identification of the communication device **10**. Upon making the transmission, the communication device **10** preferably enters the first state.

During each of the two states, the communication device **10** still wakes up and/or responds to any transmission that includes a common designation (such as a class designation) that matches a common designation of the communication device **10**. Preferably, each communication device **10** keeps a table of applicable common designations to which it belongs. In this respect, a common designation preferably is used to represent the Class-Present Wakeup Broadcast and this common designation is either enabled or disabled in the table as maintained by the communication device **10** depending upon whether the communication device **10** should respond to a Class-Present Wakeup Broadcast that is next received.

Specifically, after the communication device **10** has made a responsive transmission to a Class-Present Wakeup Broadcast, the communication device **10** preferably enables a motion sensor, disables the "present" common designation in its table, and waits to be awoken upon an indication of movement from the motion sensor. Furthermore, the enablement of the motion sensor and the disablement of the "present" common designation in its table may be automatically performed by the communication device itself following its response to the Class-Based Wakeup Broadcast, or may be performed by the communication device in direct response to instructions received from a server following the identification of the presence of the RSI to the server.

Thereafter, once the communication device **10** moves, the communication device **10** is awoken by the motion sensor and communicates, via a respective gateway, an indication of such movement to the appropriate server. The communication device **10** also then disable the motion sensor and enables the "present" common designation for waking up of the communication device **10** for response to the next Class-Present Wakeup Broadcast.

This algorithm for entering the two different states enables the communication device **10**: to "check in" when it arrives within an area of a gateway; to remain off or in standby after it has "checked in" in order to conserve internal power and avoid spurious transmissions; and to alert an appropriate server if the communication device **10** is moved.

A benefit of at least one embodiment of the invention is the avoidance of unnecessary and/or undesired radio frequency transmissions during air shipments in a cargo area of an airplane. Specifically, when communication devices **10**, preferably associated with assets being tracked and/or monitored, are loaded into the cargo area of an airplane, a Class-Present Wakeup Broadcast is made in order to identify the communication devices present for taking inventory of the cargo. An instruction then is broadcast causing the communication devices to enter the second state, in which the motion sensors then are disabled. A Class-Present Wakeup Broadcast is not made until after the airplane has arrived at its intended location.

Since the motion sensor is turned off when the "present" common designation is enabled, the communication device **10** will not continuously try to report back to the server while it is in motion in the airplane. During movement, such as that associated with air transportation, the communication device **10** thus remains in a power conservation mode until it comes within range of the next gateway and receives a Class-Present Wakeup Broadcast.

As will be appreciated from the foregoing description, the movement of a communication device **10** is tightly monitored by one or more servers, since any communication device **10** within range of a gateway **20**,**22**,**24**,**26** reports when a predefined condition, e.g., movement, has occurred that indicates that it has been likely moved out of the respective area in which it was residing. Moreover, unnecessary transmissions in response to Class-Present Wakeup Broadcasts are avoided when a communication device **10** has not moved out of the respective area in which it resides.

In alternatives to the arrangements represented in FIGS. **1**-**8**, the n servers can be consolidated into a single server; and/or one or more servers can be combined with one or more gateways. Such changes may reduce networking costs, delays, and overhead associated with asset tracking systems, but the flexibility, capabilities, and/or robustness of the systems likewise may be reduced.

One or more aspects of the invention further may be utilized with a single area for maintaining visibility of assets within the single area without regard to visibility of the assets in other areas, if desired.

Another benefit of at least one embodiment of the invention is the ability to synchronize reporting from a plurality of radio frequency communication devices to a server. In this respect, radio frequency communication devices preferably communicate data that otherwise is being stored to a server concurrently when responding to a Present Broadcast. The concurrent communication of the data with a Present Response obviates the need for the communications device to wakeup at a later time for the specific purposes of communicating the stored data. As such, a group of communication devices can be manipulated, for example, into the first state such that each responds to a Present Broadcast by communicating not only a Present Response, but the stored data at each respective communication device. Such manipulation into the first state can occur, for example, by creating a predetermined condition (e.g., change in temperature, change in location, or movement), resulting in sensor signals causing the communication devices to enter the first state from the second state; and/or by broadcasting an instruction to the communication devices to enter the first state.

In view of the foregoing, one or more benefits of one or more aspects of the present invention include: an increased battery life; the ability to transport assets by land, sea, or air without unnecessary or unwanted transmissions from the radios associated with the assets; the ability to still communicate "on demand" with a particular asset based on a common designation or class; the ability to determine assets newly arrived within an area "on demand" independent of any broadcasts at regular time intervals; the ability of an asset to "hide" from unauthorized persons by not needlessly identifying its presence in response to a general radio frequency broadcast; and the ability to determine when an asset is moved from an area once the asset has been identified as having arrived within the area.

What is claimed is:

1. A radio frequency communication device, comprising:

(a) a receiver configured to receive radio frequency transmissions;

(b) a transmitter configured to make radio frequency transmissions;

(c) an interface for receiving one or more signals from a sensor; and

(d) electronic components arranged and configured such that,

(i) the radio frequency communication device operates in at least two states comprising,

(A) a first state of operation, in which the radio frequency communication device responds to a radio frequency transmission that is received by the receiver, and that includes data representative of an inquiry as to the presence of radio frequency communication devices within a service area of a gateway configured for providing network communications to radio frequency communication devices, by making a radio frequency transmission with the transmitter that includes an identification of the radio frequency communication device, and

(B) a second state of operation, in which the radio frequency communication device does not respond to a radio frequency transmission that is received by the receiver, and that includes data representative of an inquiry as to the presence of radio frequency communication devices within a service area of a gateway configured for providing network communications to radio frequency communication devices, by making a radio frequency transmission with the transmitter that includes an identification of the radio frequency communication device, and

(ii) the radio frequency communication device enters the second state of operation from the first state of operation upon,

(A) receiving by the receiver a radio frequency transmission that includes data representative of an inquiry as to the presence of radio frequency communication devices within a service area of a gateway configured for providing network communications to radio frequency communication devices, and

(B) making a radio frequency transmission with the transmitter that includes an identification of the radio frequency communication device, and

(iii) the radio frequency communication device enters the first state of operation from the second state of operation upon,

(A) receiving, through the interface, one or more sensor signals based on sensor-acquired data that is indicative of a predetermined condition,

(B) wherein the predetermined condition is movement of the radio frequency communication device;

(e) wherein the radio frequency communication device is physically associated with an asset that is tracked in an asset tracking system, whereby the presence of the asset is determinable within a service area of a gateway configured for providing network communications to radio frequency communication devices.

2. The radio frequency communication device of **1**, wherein the electronic components are further configured such that the radio frequency communication device makes a radio frequency transmission upon receiving, through the interface, one or more sensor signals based on sensor-acquired data that is indicative of the predetermined condition.

3. The radio frequency communication device of **1**, further comprising a computer processor that processes received radio frequency transmissions and received sensor signals.

4. The radio frequency communication device of claim **1**, wherein the one or more sensor signals includes the sensor-acquired data.

5. The radio frequency communication device of claim **1**, wherein the one or more sensor signals is representative of the sensor-acquired data.

6. The radio frequency communication device of claim **1**, wherein the one or more sensor signals is representative of a state of a sensor.

7. The radio frequency communication device of claim **1**, wherein the computer processor effects state changes of the radio frequency communication device as a function of received radio frequency transmissions and one or more received sensor signals.

8. The radio frequency communication device of claim **1**, wherein the electronic components are further arranged and configured such that the radio frequency communication device enters the first state upon receiving, through the receiver, a radio frequency transmission including an instruction to enter the first state.

9. The radio frequency communication device of claim **1**, wherein the electronic components are further arranged and configured such that the radio frequency communication device enters the first state upon expiration of predetermined period of time as indicated by a timer of the radio frequency communication device.

10. The radio frequency communication device of claim **1**, wherein the electronic components are further arranged and configured such that the radio frequency communication device enters the first state after a predetermined number of failed attempts to communicate by the radio frequency communication device have occurred.

11. The radio frequency communication device of claim **1**, wherein the electronic components are further arranged and configured such that the radio frequency communication device enters the second state upon receiving, through the receiver, a radio frequency transmission including an instruction to enter the second state.

12. The radio frequency communication device of claim **1**, wherein the radio frequency communication device further comprises a component configured to detect movement of the radio frequency communication device, and wherein the one or more sensor signals are received through the interface from said component.

13. The radio frequency communication device of claim **1**, wherein the radio frequency communication device further comprises a GPS receiver component for detecting the geographical location of the radio frequency communication device, and wherein the one or more sensor signals are received through the interface from said GPS receiver component.

14. A method performed by a radio frequency communication device in an asset tracking system, the radio frequency communication device being physically associated with an asset to be tracked for determining the presence of the asset within a service area of a gateway configured for providing network communications to radio frequency communication devices, the method comprising the steps of:

(a) first, responding to a radio frequency transmission that is received by a receiver of the radio frequency communication device, and that includes data representative of a general inquiry as to the presence of radio frequency communication devices within a service area of a gateway configured for providing network communications to radio frequency communication devices, by making a radio frequency transmission with a transmitter of the radio frequency communication device that includes an identification of the radio frequency communication device, and then, not responding to subsequent radio frequency transmissions that are received by the receiver of the radio frequency communication device, and that include data representative of a general inquiry as to the presence of radio frequency communication devices within a service area of a gateway configured for providing network communications to radio frequency communication devices, by making a radio frequency transmission with the transmitter of the radio frequency communication device that includes an identification of the radio frequency communication device; and

(b) repeating said step (a) upon receiving, through an interface of the radio frequency communication device, one or more sensor signals based on sensor-acquired data that is indicative of a predetermined condition, wherein the predetermined condition is movement of the radio frequency communication device.

15. The method of claim **14**, further comprising the step of making a radio frequency transmission with the transmitter of the radio frequency communication device upon receiving, through an interface of the radio frequency communication device, one or more sensor signals based on sensor-acquired data that is indicative of the predetermined condition.

16. The method of **15**, wherein the predetermined condition comprises movement of the radio frequency communication device.

17. The method of **15**, wherein the predetermined condition comprises a change, exceeding a threshold amount, in the location of the radio frequency communication device as determined based on GPS data.

18. The method of **15**, wherein the predetermined condition comprises a temperature associated with the radio frequency communication device exceeding a predetermined threshold.

19. The method of claim **14**, wherein the radio frequency communication device is associated with an asset being tracked in an asset tracking system.

20. The method of claim **14**, further comprising repeating said step (a) after a predetermined number of failed attempts to communicate by the radio frequency communication device have occurred.

21. The method of claim **14**, further comprising repeating said step (a) in response to an instruction received by the radio frequency communication device in a radio frequency transmission.

22. The method of claim **14**, wherein the one or more sensor signals are received through the interface from a GPS receiver.

23. The method of claim **14**, wherein the one or more sensor signals are received through the interface from a motion or accelerometer sensor.

24. An asset tracking system comprising a plurality of radio frequency communication devices, each being physically associated with an asset to be tracked and each configured to,

(a) first, respond to a radio frequency transmission that is received by a receiver of the radio frequency communication device, and that includes data representative of a general inquiry as to the presence of radio frequency communication devices within a service area of a gateway configured for providing network communications to radio frequency communication devices, by making a radio frequency transmission with a transmitter of the radio frequency communication device that includes an identification of the radio frequency communication device and, thereafter, not respond to subsequent radio frequency transmissions that are received by the receiver of the radio frequency communication device, and that include data representative of a general inquiry as to the presence of radio frequency communication devices within a service area of a gateway configured for providing network communications to radio frequency communication devices, by making a radio frequency transmission with the transmitter of the radio frequency communication device that includes an identification of the radio frequency communication device, and

(b) repeat step (a) upon receiving, through an interface of the radio frequency communication device, one or more sensor signals based on sensor-acquired data that is indicative of a predetermined condition, wherein the predetermined condition is movement of the radio frequency communication device,

(c) whereby the presence of the asset is determinable within a service area of a gateway configured for providing network communications to radio frequency communication devices.

25. The asset-tracking system of claim **24**, wherein the one or more sensor signals based on sensor-acquired data that is indicative of a predetermined condition comprises sensor-acquired data that is indicative of a predetermined condition.

26. The system of claim **24**, wherein each radio frequency communication device is further configured to repeat said step (a) after a predetermined number of failed attempts to communicate by the radio frequency communication device have occurred.

27. The system of claim **24**, wherein each radio frequency communication device is further configured to repeat said step (a) in response to an instruction received by the radio frequency communication device in a radio frequency transmission.

28. The asset-tracking system of claim **24**, wherein the predetermined condition comprises the opening of a container.

29. The system of claim **24**, wherein the one or more sensor signals are received through the interface from a GPS receiver.

30. The system of claim **24**, wherein the one or more sensor signals are received through the interface from a motion or accelerometer sensor.

* * * * *